Docket No.: 4576/4581A(CON)/ENG0012-00US
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Patent Application of: GALLIGAN et al.	:
Application No.: 10/612,658	: Group Art Unit: 1793
Filed: July 2, 2003	: Examiner: Nguyen, Ngoc Yen M.
For: METAL CATALYST CARRIERS AND CATALYST MEMBERS MADE THEREFROM	: Confirmation No.: 5534

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

BRIEF ON APPEAL

Sir:

Further to the Notice of Appeal filed on October 14, 2008, for the subject application, a brief in support of the appeal is now submitted. Submission of a brief in support of the appeal in this case is due by December 14, 2008. Accordingly, this brief is being timely filed.

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REAL PARTY IN INTEREST

The real party in interest is Engelhard Corporation, now BASF Catalysts LLC.

RELATED APPEALS AND INTERFERENCES

The undersigned is not aware of any appeals or interferences that are related to this appeal, or which will affect or have a bearing on this appeal.

STATUS OF CLAIMS

Claims 1-3, 5, 6, 30-35 and 37-43 were finally rejected in an Office Action mailed on July 14, 2008 ("the Final Office Action"), and are the subject of this appeal. Claims 4, 7-29 and 36 were previously cancelled without prejudice or disclaimer.

STATUS OF AMENDMENTS

No claims have been amended, added or cancelled subsequent to the Final Office Action.

SUMMARY OF CLAIMED SUBJECT MATTER

The claimed subject matter encompasses catalyst members and catalyst assemblies comprising the same. Independent claim 1 is directed to a conformable catalyst member comprising:

> a refractory metal pliable carrier comprising a tube of corrugated construction, *(page 9, lines 18-19; Figure 3, element 46)*
>
> the tube having an elongate body portion which is dimensioned and configured to be mounted in a curved or bent configuration along its length within a bent or curved portion of an exhaust pipe having an open discharge end, *(page 8, lines 25-27; Figure 1A)*
>
> the pliable carrier having coated thereon an intermetallic anchor layer *(page 9, lines 19-20; Figure 3, element 47)* having a catalytic coating applied thereto *(page 9, lines 20-21; Figure 3, element 48)* which remains intact on the carrier when the conformable catalyst member is bent along its length and mounted within a bent or curved portion of an exhaust pipe. *(page 9, lines 24-27)*

Independent claim 34 is directed to a catalyst member for treating noxious components of engine exhaust gas:

> a pliable refractory metal carrier comprising a plurality of perforated plate members *(Figure 6, element*

76) having opposite faces and disposed in a face-to-face linear array *(Figure 7)* to impart a cylindrical shape having a length to the carrier and to form accordion pleats *(Figure 6, element 80)*, *(page 14, lines 13-16)*

the plate members having protrusions *(Figure 6A, element 78a)* extending from their faces which space adjacent plate members from each other, *(page 14, lines 8-12, 23-27)*

the carrier having coated thereon an intermetallic anchor layer *(Figure 6, element 47)* and a catalytic coating *(Figure 6, element 48)*, *(page 14, lines 4-5)*

the catalyst member being conformable along its length such that when placed in a bent or curved configuration to provide intimate contact of the exhaust gas with the catalytic coating of conformable catalyst member to promote reactions to convert noxious components of the exhaust gas, the catalytic coating remains intact on the carrier. *(page 14, lines 5-8)*

The dependent claims are directed to various embodiments of the disclosed catalyst member. In particular, claim 37 is directed to a catalytic assembly comprising the conformable catalyst member of claim 1 disposed within a bent or curved portion of an exhaust pipe having an open discharge end. *(Page 15, line 9 to page 16, line 6; Figure 9.)*

Claim 42 is directed to the catalytic assembly of claim 37, having a plurality of perforations *(Figure 4, element 254)* formed around the periphery of the carrier tube. *(Page 11, lines 7-8.)*

Claim 43 is directed to the catalytic assembly of claim 42, wherein the conformable catalyst member comprises a plurality of interior closures to prevent passage of exhaust therethrough and force passage of the exhaust out through the carrier tube perforations *(Figure 4, element 58)*, and wherein the exhaust pipe comprises a series of interior annular baffles *(Figure 4, element 60)* to prevent passage of exhaust therethrough and force passage of the exhaust in through the carrier tube perforations. *(Page 11, lines 1-16.)*

A copy of the appealed claims is appended hereto, beginning at page 23.

GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

I. Whether 1-3, 5, 6 and 31-34, 37, 38 and 40-43 are unpatentable under 35 U.S.C. § 103(a) over Ishida (US 4,455,281; "Ishida") in view of Uchida et al. (EP 0831211; "Uchida").

II. Whether claims 30, 35 and 39 are unpatentable under 35 U.S.C. § 103(a) over Ishida in view of Uchida, and further in view of Donomoto et al. (US 4,798,770; "Donomoto") or Draghi et al. (US 6,042,879; "Draghi").

III. Whether claims 1-3, 5, 6, 30-35 and 37-43 are unpatentable under 35 U.S.C. § 103(a) over Gorynin et al. (US 5,204,302; "Gorynin") in view of Uchida, optionally further in view of Rondeau (US 4,027,367; "Rondeau") and Ishida.

ARGUMENT

I. Rejection Over Ishida and Uchida

Claims 1-3, 5, 6, 31-34, 37, 38 and 40-43 Generally

Claims 1-3, 5, 6, 31-34, 37, 38 and 40-43 stand finally rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Ishida in view of Uchida. According to the Examiner in the Final Office Action, Ishida discloses a method of producing a plate-shaped catalyst unit for NOx produced by a method comprising the steps of spraying molten metal upon the surfaces of a metal plate to allow the molten metal to accumulate thereon to form rough surfaces and depositing a catalyst containing titanium and at least another catalytic material for NOx reduction of exhaust gas onto said rough surfaces whereby the catalyst is firmly secured on said rough surfaces. The Examiner acknowledges that Ishida does not disclose a tube of corrugated construction, but states that Uchida discloses an exhaust emission control device for internal combustion engines having a catalytic metal bearing (or support) member that can be a hollow cylinder (i.e., tube), which is made of a porous metal sheet or a corrugated porous plate.

In response to the Applicants arguments submitted with their Amendment and Response on April 15, 2008, that claims 1 and 34 had been amended to clarify that placement of the conformable catalyst within a bent or curved portion of an exhaust pipe is a positive claim limitation, the Examiner states in the Final Office Action that the limitation is still considered as an intended use (noting the use of the term "when"), and thus is not entitled to any patentable weight. With regard to claim 37 (and claims 38-43 dependent therefrom), the Examiner states that Uchida is further applied to teach that the

catalyst can be placed in a bent or curved portion of an exhaust pipe (noting Figures 16A-B).

Applicants maintain that the recitations in claim 1 – "an intermetallic anchor layer having a catalytic coating applied thereto which remains intact on the carrier when the conformable catalyst member is bent along its length and mounted within a bent or curved portion of an exhaust pipe" – and claim 34 – "the catalyst member being conformable along its length such that when placed in a bent or curved configuration to provide intimate contact of the exhaust gas with the catalytic coating of conformable catalyst member to promote reactions to convert noxious components of the exhaust gas, the catalytic coating remains intact on the carrier" – are positive limitations which clearly define the claimed catalyst member and thus must be considered when assessing patentability. As explained in Applicants' specification, the strong bond of the anchor layer achieved by electric arc spraying permits the resulting catalyst members to be bent, compressed, folded, rolled, curved, etc., to conform to the bent or curved portion of n exhaust pipe without loss of the catalytic coating. *See* page 10, lines 7-13.

The Examiner points to the use of the word "when" in claims 1 and 34 as evidence that what follows is a recitation of intended use. However, the use of the word "when" in the instant claims is necessary as a transitional term to define those properties of the catalyst member which make it suitable for the recited purpose (i.e., mounted within a bent or curved portion of an exhaust pipe), and thus which distinguish the claimed catalyst member from prior art catalyst members. In this respect, the claims are similar to claim 9 at issue in *In re Watanabe*, 315 F.2d 924 (CCPA 1963), which read:

> 9. An electrode component formed of a powdered metal and a powdered salt of the metal <u>which will produce an</u>

> electromotive force when inserted into a solution of salt, the electrode component comprising a mixture of the metal and metal salt compressed into a substantially nonporous integral mass.

Id. at 926 (emphasis added).

The Solicitor in *Watanabe* argued that "the clause 'which will produce an electromotive force when inserted into a solution of a salt' contained in claim 9 is merely a statement of intended use which cannot impart patentability to the electrode defined in the claim." *Id.* at 928. The court disagreed, finding that "this limitation was intended and should be interpreted as modifying the word 'electrode.'" *Id.* The court noted that electrodes are of many types, each type having particular physical or chemical properties adapting it for use in a particular installation, and, as such, "an 'electrode which will produce an electromotive force when inserted into a solution of salt' as called for in claim 9 defines an electrode having particular properties making it adaptable to a particular purpose." *Id.* The court concluded that "claim 9 properly defines a particular type of electrode which, as shown in the affidavit, has significant advantages over any electrode of the prior art when used for the particular purpose for which it is intended." *Id.*

As with claim 9 in *Watanabe*, claims 1 and 34 properly define a particular type of catalyst member in terms of its conformability that is clearly not taught or suggested in the references cited by the Examiner. *See also In re Stencel*, 828 F.2d 751, 752-54 (Fed. Cir. 1987) ("As a matter of claim draftsmanship, appellant is not barred from describing the driver in terms of the structure imposed upon it by the collar having plastically deformable lobes ['A driver for setting a joint of a threaded collar . . . having plastically deformable lobes . . ., the driver comprising . . .']. The framework – the teachings of the prior art – against which patentability is measured is not all drivers broadly, but drivers

suitable for use in combination with this collar, for the claims themselves are so limited.").[1]

As explained by Michael P. Galligan in his Declaration Under 37 C.F.R. § 1.132 ("Galligan Declaration"; appended hereto beginning at page 27), there is no teaching or suggestion in Ishida of a catalyst member that can be bent or curved so that the catalyst member can be inserted into a bent or curved engine exhaust pipe. The Examiner cites to col. 3, lines 60-63 and Figures 3 and 4 of Ishida as teaching that the metal plates can be subjected to bending, but Mr. Galligan notes that it is important to recognize the between what Ishida designates bare metal plates 5 and catalyst unit 3, which is a metal plate with catalyst substance 11 on its surface. *See* paragraph 12. Although the bare metal plate can be bended, there is absolutely no indication that the catalyst unit is designed or intended to be bent, or that catalyst substance would remain intact on the plate if so bent, as required by the instant claims. Figure 1 of Ishida actually shows the complete opposite, namely placement of the catalyst units in a linear fashion in the reactor, with no plates in the curved ducts leading into and out of the reactor.

Indeed, as noted by Mr. Galligan, Ishida explicitly teaches that it is undesirable to bend or deform the catalyst member. *See* paragraph 13. At col. 2, lines 5-14, Ishida describes problems associated with prior art catalyst units, including the falling off of catalytic substances from metal plates or wire mesh subjected to even slight deformation. Ishida further teaches at col. 4, lines 47-52, that the "the size and thickness of the metal

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[1] Claims 37-43 depend from claim 1 and are directed to a catalytic assembly comprising the conformable catalyst member of claim 1 disposed within a bent or curved portion of an exhaust pipe having an open discharge end. As the Examiner has acknowledged that these claims positively recite placement of the catalyst member within a bent or curved portion of an exhaust pipe, this limitation must be considered in assessing patentability independent of the decision on claim 1 regarding intended use.

plate is suitably selected depending on the dimensions of the apparatus for exhaust gas denitrification, the amount of catalyst to be held by the metal plate. The thickness is preferably thin, but toughness of the metal plate is required in order not to easily yield to deformation." As Mr. Galligan explains, it is important to note in this passage that, based on the phrase "amount of catalyst ***to be held*** by the metal plate," Ishida is discussing a bare metal plate, and that no catalyst has yet been applied to the plate. As a person skilled in the art would recognize, a plate that is "tough" and that does "not easily yield to deformation" refers to a rigid plate, thus teaching away from the conformable catalyst member bendable along its length for mounting within a bent or curved portion of an exhaust pipe recited in the instant claims. *See KSR*, 127 S. Ct. at 1740 ("[W]hen the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be nonobvious) (citing *United States v Adams*, 383 U.S. 39, 51-52 (1966)).

Uchida does not cure the deficiencies of Ishida regarding conformability. Contrary to the Examiner's assertion, Figures 16A-B of Uchida does not disclose that the catalyst can be placed in a bent or curved portion of an exhaust pipe. As explained by Mr. Galligan, although exhaust purifying apparatuses 61 and 63 contain curved portions, none of the exhaust purifiers 10 and 50 are positioned in the curved portions. Rather, they are all placed in the linear regions of the apparatuses due to the fact that they are not conformable or bendable, as shown in Figure 12 of Uchida. Thus, even if combined, Ichida and Uchida do not teach or suggest placement of a conformable catalyst member within a bent or curved portion of an exhaust pipe, let alone retention of the catalytic coating following such placement. *See In re Royka*, 490 F.2d 981, 985 (CCPA 1974).

Accordingly, Applicants maintain that the Examiner has failed to make out a *prima facie* case of obviousness of claims 1 and 34 (and claims 2, 3, 5, 6, 31-33, 37, 38 and 40-43 dependent therefrom) over Ishida in view of Uchida, and reversal of the rejection is respectfully requested.

Furthermore, Applicants maintain that any evidence of obviousness in view of Ishida and Uchida has been successfully rebutted by the data submitted in paragraphs 5-10 and Exhibit A of the Galligan Declaration. These portions of the Galligan Declaration describe the results of testing of the claimed conformable catalyst member compared to a rigid catalyst member of the type described in Uchida. In each test, the conformable catalyst member exhibited unexpectedly superior results compared to the rigid catalyst member. For example, a 19-mm conformable catalyst member (designated Flextube™) unexpectedly had hydrocarbon conversions from 5% to 15% greater, and CO conversions between 0% and 15% greater, than those of a 21-mm rigid tube in a bench engine evaluation. A 24-mm Flextube™ unexpectedly had hydrocarbon conversions from 5% to 20% greater, and CO conversions between 10% and 20% greater, than those of a 27-mm rigid tube in a bench engine evaluation.

In another set of experiments, a 19-mm OD x 260-mm L Flextube™ and a 21-mm OD x 260-mm L rigid tube were both catalyzed with 20/1 Pt/Rh. The Flextube™ was tested in a close-coupled position in an actual motorcycle engine test, with the inlet located 50 mm downstream of the engine exhaust port. Both the Flextube™ and the rigid tube were tested at a location where the inlet was 300 mm downstream of the engine exhaust port. The results for the conformable catalyst member, were unexpectedly good, as the close-coupled Flextube™ achieved twice the hydrocarbon conversion and 50%

more CO conversion as the rigid tube located 300 mm downstream. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, the HC conversion increased from 63% to 81%, and the CO conversion increased from 47% to 62%.

Applicants maintain that such results clearly are unexpected and commensurate in scope with the claimed invention and must be considered when assessing patentability. *See In re Soni*, 54 F.3d 746, 750 (Fed Cir 1995) ("Consistent with the rule that all evidence of nonobviousness must be considered when assessing patentability, the PTO must consider comparative data in the specification in determining whether the claimed invention provides unexpected results."). As discussed above, the instant claims are directed to a conformable catalyst member whose catalytic coating remains intact when the catalyst member is bent along its length and mounted within a bent or curved portion of an exhaust pipe. Since neither Ishida nor Uchida discloses a catalyst member that can conform to a bent or curved portion of an exhaust pipe, the use of a rigid tube placed in a linear portion of the exhaust pipe was a proper comparison for the testing described in the Galligan Declaration.

In addition, the instant claims are concerned with the treatment of exhaust gas. As such, Applicants submit that the results from testing of the catalyst member in a close-coupled position in the exhaust stream of a motorcycle are commensurate with the scope of the claims, particularly since unexpected results were achieved even in this severe testing environment.

Accordingly, Applicants maintain that claims 1 and 34 (and claims 2, 3, 5, 6, 31-33, 37, 38 and 40-43 dependent therefrom) are patentable over Ishida in view of Uchida, and reversal of the rejection is respectfully requested.

Claim 5

Applicants also submit that claim 5, which depends from claim 1, is patentable over Ishida in view of Uchida for the additional reason that the claim requires that the tube of corrugated construction comprises alternating rings separated by annular webs. The Examiner has failed to point to anything in Ishida or Uchida that teaches or suggests this limitation. Indeed, the rigid hollow tubes shown in Uchida clearly lack annular webs. *See, e.g.*, Figures 5, 6 and 9-16 of Applicant's application.

Accordingly, Applicants submit that claim 5 is independently patentable over Ishida in view of Uchida apart from the reasons given above with respect to claim 1, and reversal of the rejection is respectfully requested.

Claim 34

Claim 34 contains the further limitations of catalyst member that includes a plurality of perforated plate members having opposite faces and disposed in a face-to-face linear array to impart a cylindrical shape having a length to the carrier and to form accordion pleats, the plate members having protrusions extending from their faces which space adjacent plate members from each other. Such a structure is show in Figures 6 and 7 of Applicant's patent application. No such structure is taught or suggested in Ishida and Uchida. As such, claim 34 is separately patentable over the cited references.

Claims 31-33 and 40-41

Claim 31 depends from claim 1, and claim 40 depends from claim 37, which depends from claim 1. Claims 31 and 40 further recite that the carrier has a distal end and a proximal end, the proximal end comprising a mounting member dimensioned and configured to be secured to the open discharge end of the pipe when the body portion of the carrier is disposed within the pipe. Claim 32 depends from claim 31, and claim 41 depends from claim 40. Claims 32 and 41 recites the annular collar as defining a mounting flange disposed radially outwardly of the proximal end of the catalyst member. Claim 32 further requires that the recites structure defines between the mounting flange and the proximal end of the catalyst member an annular slot which is dimensioned and configured to receive therein the open discharge end of the pipe, when the body portion of the carrier is disposed within the pipe. Claim 33 depends from claim 32 and recites that catalytic material is coated on at least some of the body potion of carrier. See Figures 5A and 5B of Applicant's patent application.

Claims 31 and 40

In the Final Office Action, the Examiner appears to deem the limitations of claim 32 and 40 as the mere recitation of intended use. Claim 31 clearly recites that the carrier has a mounting member that can be secured to the open end of the pipe. No such structure is taught or suggested in the cited references. In Uchida, item 23 in Figures 5-6 is cited as disclosing such structure, but this structure is clearly mounted inside the pipe and not on the open end of the pipe. It is also clear that item 23 does not appear that it could be secured to the open end of the pipe, as there is no structure shown or described

for mounting to the open end of the pipe. As such claims 31 and 40 are independently patentable over the cited references.

Claims 32 and 41

Claims 32 and 41 recites additional structural features of the mounting member, namely that the mounting member comprises an annular collar defining a mounting flange disposed radially outwardly of the proximal end of the catalyst member to define an annular slot. These features are not shown or suggested in the cited references. Particularly, item 23 in Uchida lacks any such structure that defines an annular slot that can receive the open end of the pipe. As such, claims 32 and 41 are independently patentable over the cited references.

Claims 42 and 43

Claim 42

Applicants also submit that claim 42, which depends from claim 1 and claim 43, which ultimately depends from claim 1, is patentable over Ishida in view of Uchida for the additional reason that the claim is directed to a catalytic assembly comprising the conformable catalyst member of claim 1 disposed within a bent or curved portion of an exhaust pipe and requires that the carrier tube comprises a plurality of perforations around the periphery of the carrier tube. The cited references do not teach or suggest a carrier tube comprising a plurality of perforations around the periphery of the carrier tube.

Claim 43

Claim 43 further recites a plurality of interior closures to prevent passage of exhaust therethrough and force passage of the exhaust out through the perforations of the

carrier tube, and wherein the exhaust pipe comprises a series of interior annular baffles to prevent passage of exhaust therethrough and force passage of the exhaust in through the perforations of the carrier tube. The Examiner has failed to point to anything in Ishida or Uchida that teaches or suggests these limitations. Indeed, the gas flow arrows shown in Figures 6 and 11 of Uchida clearly indicate that the hollow rigid tubes lack any structure capable of redirecting gas flow.

Accordingly, Applicants submit that claim 43 is independently patentable over Ishida in view of Uchida apart from the reasons given above with respect to claim 1, and reversal of the rejection is respectfully requested.

II. <u>Rejection Over Ishida, Uchida and Donomoto or Draghi</u>

Claims 30, 35 and 39 stand finally rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Ishida in view of Uchida as applied above, further in view of Donomoto or Draghi. According to the Examiner in the Final Office Action, although Ishida does not disclose that the anchor layer comprises nickel and aluminum, Ishida does teach that the molten sprayed metal is preferred to be the same type of material as the metal plate, which is desired to be heat and corrosion resistant, such as stainless steel. According to the Examiner, however, Ishida should not be limited to just the exemplified metals. In this respect, the Examiner states that Donomoto discloses that alloys, including Ni-Cr, Ni-Al, Ni-Cr-Al and Ni-Cr-Al-Y, are heat and corrosion resistant, or alternatively, Draghi discloses that MCrAlY, where M is nickel and/or cobalt, has corrosion and heat resistant properties. Thus, according to the Examiner, it would have been obvious to use any of the alloys suggested by Donomoto or Draghi for the catalyst in Ishida because heat and corrosion resistance is desired in Ishida,

Claims 30 and 39 depend directly or indirectly from claim 1, and claim 35 depends directly from claim 34. Where, as here, an independent claim is valid over cited art, *a fortiori* any claim dependent therefrom must also be valid over the same art. *See Panduit Corp. v. Dennison Mfg. Co.*, 810 F.2d 1561, 1576 n.36 (Fed. Cir. 1987). As discussed above with respect to the rejection of claims 1 and 34 over Ishida and Uchida alone, there is no teaching or suggestion in Ishida or Uchida of a catalyst member that can conform to the bend or curve in an engine exhaust pipe, or that any catalytic coating thereon would remain intact upon bending or curving. Furthermore, the Examiner has failed to point to anything in Donomoto or Draghi that remedies the deficiencies of Ishida and Uchida regarding conformability. As such, the combination of Ishida and Uchida with Donomoto or Draghi cannot render the claimed invention obvious. *See In re Rijckaert*, 9 F.3d 1531, 1533 (Fed Cir. 1993).

Accordingly, Applicants maintain that claims 30, 35 and 39 are patentable over Ishida in view of Uchida, further in view of Donomoto or Draghi, and reversal of the rejection is respectfully requested.

III. <u>Rejection Over Gorynin, Uchida, Rondeau and Ishida</u>

Claims 1-3, 5, 6, 30-35 and 37-43 stand finally rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Gorynin in view of Uchida, optionally further in view of Rondeau and Ishida. According to the Examiner in the Final Office Action, Gorynin discloses a catalyst comprising a metallic substrate, an adhesive sublayer applied by plasma spraying of thermally reactive powders prepared from nickel and titanium, and a catalytically active layer, which can be rolled into a corrugated cylinder. Rondeau is optionally applied to teach the use of electric arc spraying to form the adhesive layer in

Gorynin, and can be further applied to teach a wire alloy of 93% nickel, from 4-5.2% aluminum and from 0.25-1% Ti. Ishida is optionally applied as above to teach forming an adhesive layer on a catalyst substrate by electric arc spraying, and Uchida is again relied upon to teach the desired shape of the catalyst member, i.e., a hollow cylinder which can be positioned in a curve or bent portion of an exhaust pipe.

Claims 1-3, 5, 6, 31-34, 37, 38 and 40-43 Generally

As discussed above with respect to the rejection of claims 1-3, 5, 6, 31-34, 37, 38 and 40-43 over Ishida and Uchida alone, neither Ishida nor Uchida teaches or suggests a catalyst member that can conform to the bend or curve along its length in an exhaust pipe, or that any catalytic coating thereon would remain intact upon bending or curving along its length. Furthermore, the Examiner has failed to point to anything in Gorynin or Rondeau that remedies the deficiencies of Ishida and Uchida regarding conformability. As such, the combination of Ishida and Uchida with Gorynin or Rondeau cannot render the claimed invention obvious. *See In re Rijckaert*, 9 F.3d 1531, 1533 (Fed Cir. 1993).[2]

Moreover, in the Final Office Action, the Examiner states that "it would have been obvious to roll the corrugated catalyst strip of Goryinin into a hollow cylinder as suggested by Uchida because such shape is desirable for an analogous application." The rejection based on the cited reference fails to establish that it would have been prima facie obvious to provide a catalyst member that can be mounted in a curved or bent configuration along its length within a bent or curved portion of an exhaust pipe.

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[2] The unexpected results in the Galligan Declaration discussed above with respect to the rejection of claims 1-3, 5, 6, 31-34, 37, 38 and 40-43 over Ishida and Uchida alone are equally applicable to the rejection over Gorynin, Uchida, Rondeau and Ishida. As such, Applicants maintain that any evidence of obviousness in view of these references has been successfully rebutted.

Gorynin is cited as teaching rolling a corrugated catalyst strip into a cylinder having a length of 30 mm in length and 20-50 mm in diameter at col. 9, lines 62-68. However, such a cylindrical catalyst member would hardly provide a catalyst member that can be mounted in curved or bent configuration along its length within a bent or curved portion of an exhaust pipe. The Examiner fails explain how the combined teachings of Gorynin and Uchida would teach a conformable catalyst member that can be curved or bent along its length.

<u>**Claim 5**</u>

The arguments above with respect to claim 5 above are repeated and reiterated here, as there is nothing in Gorynin to remedy the deficiencies noted above in Ishida and Uchida.

<u>**Claim 34**</u>

The arguments above with respect to claim 34 above are repeated and reiterated here, as there is nothing in Gorynin to remedy the deficiencies noted above in Ishida and Uchida.

<u>**Claims 31-33 and 40-41**</u>

The arguments above with respect to claim 31-33 and 40-41 above are repeated and reiterated here, as there is nothing in Gorynin to remedy the deficiencies noted above in Ishida and Uchida.

<u>**Claims 42 and 43**</u>

The arguments above with respect to claim 42 and 43 above are repeated and reiterated here, as there is nothing in Gorynin to remedy the deficiencies noted above in Ishida and Uchida.

Accordingly, Applicants maintain that claims 1-3, 5, 6, 30-35 and 37-43 are patentable over Gorynin in view of Uchida, optionally further in view of Rondeau and Ishida, and reversal of the rejection is respectfully requested.[3]

[3] Applicants submit that claims 5 and 43 are independently patentable for the reasons given above with respect to their rejection over Ishida and Uchida alone.

CONCLUSION

For the foregoing reasons, Applicants maintain that claims 1-3, 5, 6, 30-35 and 37-43 meet the requirements for patentability under 35 U.S.C. § 103. Accordingly, reversal of the Examiner's rejections is appropriate and is respectfully solicited.

Respectfully submitted,

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CLAIMS APPENDIX

1. A conformable catalyst member comprising a refractory metal pliable carrier comprising a tube of corrugated construction, the tube having an elongate body portion which is dimensioned and configured to be mounted in a curved or bent configuration along its length within a bent or curved portion of an exhaust pipe having an open discharge end, the pliable carrier having coated thereon an intermetallic anchor layer having a catalytic coating applied thereto which remains intact on the carrier when the conformable catalyst member is bent along its length and mounted within a bent or curved portion of an exhaust pipe.

2. The catalyst member of claim 1 having a plurality of perforations formed around the periphery of the tube.

3. The catalyst member of claim 1 having a catalytic coating on the anchor layer to provide a conformable catalyst member.

5. The catalyst member of claim 1, wherein the tube of corrugated construction comprises alternating rings separated by annular webs.

6. The catalyst member of claim 1 wherein the anchor layer is electric arc sprayed.

30. The catalyst member of claim 1 wherein the intermetallic anchor layer is selected from the group consisting of nickel, Ni/Cr/Al/Y, Co/Cr/Al/Y, Fe/Cr/Al/Y,

Co/Ni/Cr/Al/Y, Fe/Ni/Cr, Fe/Cr/Al, Ni/Cr, Ni/Al, 300 series stainless steels, 400 series stainless steels, Fe/Cr and Co/Cr, and mixtures of two or more thereof.

31. The catalyst member of claim 1, the carrier having a distal end and a proximal end, the proximal end comprising a mounting member dimensioned and configured to be secured to the open discharge end of the pipe when the body portion of the carrier is disposed within the pipe.

32. The catalyst member of claim 31 wherein the mounting member comprises an annular collar defining a mounting flange which is disposed radially outwardly of the proximal end of the catalyst member and extends in the direction from the proximal end towards the distal end thereof, whereby to define between the mounting flange and the proximal end of the catalyst member an annular slot which is dimensioned and configured to receive therein the open discharge end of the pipe, when the body portion of the carrier is disposed within the pipe.

33. The catalyst member of claim 32 having a catalytic material coated on at least some of the body portion of the carrier.

34. A catalyst member for treating noxious components of engine exhaust gas comprising a pliable refractory metal carrier comprising a plurality of perforated plate members having opposite faces and disposed in a face-to-face linear array to impart a cylindrical shape having a length to the carrier and to form accordion pleats, the plate members

having protrusions extending from their faces which space adjacent plate members from each other, the carrier having coated thereon an intermetallic anchor layer and a catalytic coating, the catalyst member being conformable along its length such that when placed in a bent or curved configuration to provide intimate contact of the exhaust gas with the catalytic coating of conformable catalyst member to promote reactions to convert noxious components of the exhaust gas, the catalytic coating remains intact on the carrier.

35. The catalyst member of claim 34, wherein the intermetallic anchor layer is selected from the group consisting of nickel, Ni/Cr/Al/Y, Co/Cr/Al/Y, Fe/Cr/Al/Y, Co/Ni/Cr/Al/Y, Fe/Ni/Cr, Fe/Cr/Al, Ni/Cr, Ni/Al, 300 series stainless steels, 400 series stainless steels, Fe/Cr and Co/Cr, and mixtures of two or more thereof.

37. A catalytic assembly comprising the conformable catalyst member of claim 1 disposed within a bent or curved portion of an exhaust pipe having an open discharge end.

38. The catalytic assembly of claim 37, wherein the intermetallic anchor layer is electric arc sprayed.

39. The catalytic assembly of claim 37, wherein the intermetallic anchor layer is selected from the group consisting of nickel, Ni/Cr/Al/Y, Co/Cr/Al/Y, Fe/Cr/Al/Y, Co/Ni/Cr/Al/Y, Fe/Ni/Cr, Fe/Cr/Al, Ni/Cr, Ni/Al, 300 series stainless steels, 400 series stainless steels, Fe/Cr and Co/Cr, and mixtures of two or more thereof.

40. The catalytic assembly of claim 37, the carrier having a distal end and a proximal end, the proximal end comprising a mounting member dimensioned and configured to be secured to the open discharge end of the exhaust pipe when the body portion of the carrier is disposed within the exhaust pipe.

41. The catalytic assembly of claim 40, wherein the mounting member comprises an annular collar defining a mounting flange which is disposed radially outwardly of the proximal end of the catalyst member and extends in the direction from the proximal end towards the distal end thereof, whereby to define between the mounting flange and the proximal end of the catalyst member an annular slot which is dimensioned and configured to receive therein the open discharge end of the exhaust pipe, when the body portion of the carrier is disposed within the exhaust pipe.

42. The catalytic assembly of claim 37, having a plurality of perforations formed around the periphery of the carrier tube.

43. The catalytic assembly of claim 42, wherein the conformable catalyst member comprises a plurality of interior closures to prevent passage of exhaust therethrough and force passage of the exhaust out through the carrier tube perforations, and wherein the exhaust pipe comprises a series of interior annular baffles to prevent passage of exhaust therethrough and force passage of the exhaust in through the carrier tube perforations.

EVIDENCE APPENDIX

Below is the Declaration of Michael P. Galligan Under 37 C.F.R. § 1.132, submitted on October 30, 2007.

S/N 10/612,658 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Miehael P. Galligan et al.	Examiner: Ngoc Yen M Nguyen
Serial No.:	10/612,658	Group Art Unit: 1754
Filed:	July 2, 2003	Docket: 4576/4581A
Conf. No.:	5534	
Title:	Pliable Metal Catalyst Carriers, Conformable Catalyst Members Made Therefrom and Methods of Installing the Same	

DECLARATION UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Miehael P. Galligan, hereby declare that:

1. I am a citizen of the United States residing in Cranford, New Jersey.

2. I received my undergraduate degree in Bio-Chemical Sciences from West Virginia University in 1980 and an M.S. degree in Chemistry / Business Sciences from West Virginia University 1983. I have also received associate degrees in biological science and environmental engineering, and I received a B.S. in Chemistry from Kean University in 1986.

3. My research specialty is in the field of catalysts, particularly mixed-phase catalysts, including slurries of solids and liquids. My work in the field of catalysts began in 1987 when I was employed at Engelhard Corporation, now BASF Catalysts LLC, the assignee of the present invention. My work includes research and development of aircraft catalysts, automotive catalysts, diesel catalysts, and small engine and motorcycle catalyst, and in particular, the application of mixed-phase catalysts to metallic substrates.

4. I am a co-inventor on at least 20 patents worldwide, and I have authored or co-authored several technical papers in the field of catalysts.

5. Exhibit A attached hereto is a conference paper presented in Pisa, Italy at a Society of Automotive Engineers Conference in July 2001, entitled "Flextube™ Catalyst Performance In 4-Stroke Motorcycle Exhaust Systems Is Demonstrated", which demonstrates unexpected results associated with the invention defined by the amended claims in the application referenced above.

6. In Exhibit A, conformable catalyst members as described and claimed in the patent

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application referenced above were tested and compared to rigid heat tubes for catalytic activity when inserted in the exhaust pipe of a 4-stroke motorcycle engine. The performance of conformable catalyst members was compared to rigid heat tubes having similar dimensions and under similar conditions.

7. As discussed on page 5 of Exhibit A, e 19-mm conformable catalyst members, referred to as Flextube™, unexpectedly had HC conversions from 5% to 15% greater, and CO conversions between 0% and 15% greater, than those of a 21-mm rigid tube. A 24-mm Flextube™ unexpectedly had HC conversions from 5% to 20% greater, and CO conversions between 10% and 20% greater, than those of a 27-mm rigid tube.

8. As discussed on page 9 of Exhibit A, a 24-mm OD Flextube™ unexpectedly achieved higher CO conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340°C, the Flextube™ achieved 83% CO conversion and the rigid tube achieved about 70% CO conversion. The Flextube™ unexpectedly achieved higher CO conversions than the rigid tube under all steady-state conditions except the last condition. At this condition, the exhaust became rich, and the higher HC conversion of the Flextube™ resulted in higher CO make in the rich exhaust.

9. As discussed on page 9 of Exhibit A, in R40 engine testing, which involved using a 4-stroke, 80-cc motorbike to evaluate samples over the ECE R40 drive cycle, a 19-mm OD Flextube™ achieved HC and CO reductions of 63% and 47%, respectively. A 21-mm OD rigid heat tube achieved 38% HC reduction and 40% CO reduction. A 24-mm OD Flextube™ achieved 59% HC reduction and 32% CO reduction, and the 27-mm OD rigid heat tube achieved 44% HC reduction and 29% CO reduction.

10. In another set of tests, discussed at page a 19-mm OD x 260-mm L Flextube™ and a 21-mm OD x 260-mm L rigid tube were both catalyzed with 20/1 Pt/Rh. The Flextube™ was tested in a close-coupled position, with the inlet located 50 mm downstream of the engine exhaust port. Both the Flextube™ and the rigid tube were tested at a location where the inlet was 300 mm downstream of the engine exhaust port. The results for the conformable catalyst member Flextube™ were unexpectedly good, as the close-coupled Flextube™ achieved twice the HC conversion as the rigid tube located 300 mm downstream. The close-coupled Flextube™ achieved 50% more CO conversion than the rigid tube located 300 mm downstream. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, the HC conversion increased from 63% to 81%, and the CO conversion increased from 47% to 62%. While the Flextube™ is similar in configuration to the tubular member recited in claim 1 and its dependent claims, I expect that a catalyst member having the configuration as recited in claims 34 and 35 would produce similar results since they are bendable and able to be inserted into the curved or bent portion of an exhaust pipe and able to be placed in a closely coupled position to increase turbulent flow.

11. I have reviewed the Examiner's Answer mailed on July 13, 2007 and the references relied upon by the Examiner in rejecting the claims then pending in the application referenced above. None of the cited references, alone or in combination, teaches or

suggests the claimed invention of the instant patent application.

12. Regarding United States Patent No. 4,455,281 (Ishida), this referenee does not teach or suggest a conformable or bendable catalyst member. More specifically, there is no teaching or suggcstion in Ishida of a catalyst member that can be bent or curved so that the catalyst member can be inserted into a bent or curved engine exhaust pipe. The Examiner's Answer cites column 3, lines 60-63 of Ishida to support the rejection that the catalyst members can be subjected to bending. It is important to note a distinction in what Ishida between the bare **metal plates 5** and **a catalyst unit 3**, which is a metal plate with a catalyst substance 11 on the metal plate. This distinction is important when reading Ishida because bending **a bare metal plate** without an intermetallic anchor laycr or a catalyst coating thereon, as discusscd at column 3, lines 60-63 of Ishida is not considered to bc novel or unobvious. What I do consider novel and unobvious is providing a conformable catalyst mcmber having an intermetallic anchor layer on a metal carrier that can be bent along its length and inserted into a curved or bent exhaust pipc, and retain a catalytic coating on the carrier member after the catalyst member has been bent. These features are not described or suggested in Ishida.

13. Ishida actually tcaches that it is undesirable to bend or deform the catalyst member. At column 2, lines 5-14, Ishida teaches of the undesirable falling off of catalytic substance when metal plates or wire meshcs containing catalytic substance are bent. Ishida further teaches (at column 4, lincs 47-52) that the that "the size and thickness of the **metal plate** is suitably selected depending on the dimensions of the apparatus for exhaust gas denitrification, the **amount of catalyst to be held by the metal plate**. The thickness is preferably thin, but **toughness of the mctal plate is required in order not to easily yield to deformation**." (emphasis added) It is important to note in this passage that Ishida emphasizes that Ishida is discussing a bare metal plate, and that no catalyst has yet been applied to the plate, based on thc underlined passage "amount of catalyst to be held by the metal plate." Furthermore, as a person skilled in thc art, a plate that is "tough" and that does "not easily yield to deformation" refers to a rigid plate and teaches away from the invention claimed in the application referenced above.

14. Regarding thc references rclied upon on page 14 of the Examiner's Answer to characterize "toughness" of metal plates, it is my opinion that each of these citations is taken out of context and do not pertain the field of metal plates used for catalysts. Starting with Dean et al (2001/0006008), the passage citcd in the Examiner's Answer states:

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> [0022] The plate material of the collector of the present invention is any that is sufficiently flexible. A particular embodiment of the present collector is elastically flexible, so that it will recover its own, basic shape without the need for any intervention. The elastically flexible material will allow the plate to bend to the shape of the surface against which it is used but which will not allow the collected hydrogen to diffuse through and so be lost before detection and measurement. Embodiments of the plate body are made of a metal, a metallized plastic, or a plastic/metal laminate. The dimensions—and specifically the thickness—of the plates are such as to afford it the desired flexibility. One embodiment of the plate of the present invention is stainless steel, being particularly tough and sufficiently flexible to be suitable. Other embodiments of the plate of the present invention are made of plastic.

This passage, from a patent related to a plate for a hydrogen collector device, merely states that plates must be of a thickness (i.e. sufficiently thin) so that they can be flexible and be bent. This paragraph teaches the opposite of Ishida, which requires the plates to be sufficient thick so they cannot be bent.

15. Regarding Tormala et al. (6,221,075), related to an implantable bone fixation plate, the passage cited in the Examiner's answer is reproduced below:

> The main advantage of metallic plates (like titanium, stainless steel and cobalt chrome molybdenum plates), is that they are strong, tough and ductile so that they can be deformed or shaped (e.g., bended) at room temperature in the operation room, either by hand or with special instruments, to a form corresponding to the surface topography of bone to be fixed. In this way, the plate can be fixed flush on the bone surface to which the plate is applied.

This passage teaches that metallic plates can be tough and ductile. Toughness and flexibility (or deformation) of a metal plate should not be confused. Toughness refers to the resistance to fracture of a material when stressed. Toughness is defined as the amount of energy that a material can absorb before rupturing, and can be found by taking the area (i.e., by taking the integral) underneath the stress-strain curve. It is important to note that ductility is the mechanical property of being capable of sustaining large plastic deformations due to tensile stress without fracture (in metals, such as being drawn into a wire). Ductility is characterized by the material flowing under shear stress. It is contrasted with brittleness. Therefore, when the passage quoted above says that a material is tough and ductile, this does not take into account the thickness of the metal plate and its flexibility or deformation due to bending.

16. Regarding Grothues-Spork et al. (5,713,906), which relates to a prosthesis chisel tip, the passage cited in the Examiner's Answer states:

> According to a preferred embodiment of the invention the chisel blade is made of a flexible flat strip of tough, resilient material, for instance of a flat strip of resilient stainless steel. In order to achieve an optimal fit with respect to the shaft surface of the endoprosthesis to be removed, the flat strip may have a bend or wave contour perpendicular to its longitudinal extension. In this case, the chisel blade may consist of a shape memory alloy, especially a nickel-titanium alloy or of a resilient synthetic material. In order to ensure the necessary flexibility, the chisel blade has a thickness of 0.2 to 0.6 mm. Chisel blades having different thicknesses

This passage makes the point that the chisel tip should be tough (i.e. resistant to fracture when stressed), but also sufficiently thin (0.2 to 0.6 mm) to remain flexible. It is submitted that at a certain thickness, the chisel tip would remain tough, but it would no longer be flexible, meaning that it would be able to be bent or deformed by applying a bending stress. Ishida refers to this concept that a plate should be tough and thick enough to not yield to deformation, which teaches away from my claimed invention.

17. Regarding EP0831211, this reference does not teach or suggest a corrugated tubular catalyst member that can be bent along its length so that it can be placed in a curved or bent exhaust pipe of an engine. In particular, I have reviewed Figures 16A and 16B and 16D and the text accompanying these Figures, which are relied upon in the Examiner's Answer as allegedly teaching a flexible catalyst member. The text of EP0831211 at column 13, lines 10-24 states that the exhaust purifier 50 in Figure 16B, which the Examiner's Answer (at page 16, lines 12-14) maintains is conformable, is not conformable or bendable along its length. Column 13, lines 14-17 states that the central exhaust purifier is constructed in the same manner as the downstream exhaust purifier 50 of Figure 12. The exhaust purifier in Figure 16A is also the same as the purifier shown in Figure 12 (see column 13 lines 7-9). A study of the purifier of Figure 12 shows that the purifier 50 is a <u>straight</u> unit containing a first catalytic bearing member 51 and a second catalytic metal bearing member 52, which is a straight plate. Figure 12 is reproduced below:

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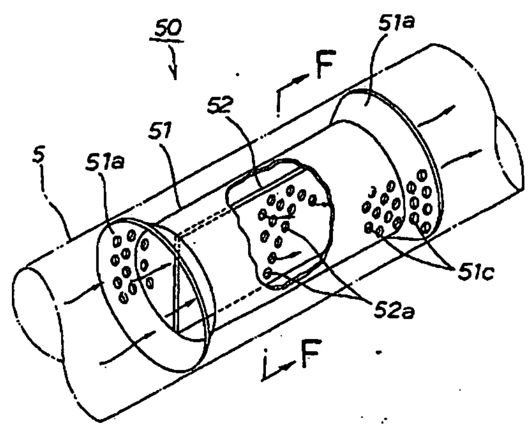
FIG. 12



As is clear from the reproduetion of Figurc 12, the exhaust purifier 50 is not at all conformable or bendable. It is a rigid cylindrical member housing a rigid straight plate, similar to the rigid tubes tested in Exhibit A and that had properties inferior to the conformable eatalyst members. In Figures 16A and 16B relied upon in the Examiner's Answer, the exhaust purifier 50 is arguably shown as slightly curved, but it is submitted this may be due to a distortion of element 50 in the drawing. To the extent it is maintained that the exhaust purifier 50 is shown as curved, this does not teach or suggest a conformable or bendable eatalyst member that can be inscrted into a bent or curved exhaust pipe and in which catalytie coating remains intact when the carrier is curved or bent along its length.

18. Regarding the strueture shown in Figure 16D, which is reprodueed below,

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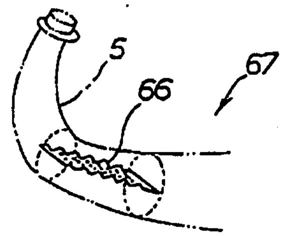
FIG. 16D



element 66 is described as a flat, porous corrugated steel sheet. There is no teaching or suggestion in the text associated with Figure 16D (namely column 13, lines 25-38) that the sheet 66 is bendable or will retain coating when inserted into a curved or bent exhaust pipe and bent along its length. It is important to note that the sheet 66 in Figure 16D is shown in a flat configuration, and the leading end of the sheet is placed at the curved portion of the exhaust pipe 5, and not inserted into the curved portion. This suggests that the sheet 66 may not be of an appropriate thickness to be bent and is not flexible. It is also important to note that a sheet of metal can be corrugated, yet it may not be flexible. For example, a sheet of corrugated steel used in the construction of industrial buildings has corrugations, but it is not easily bent or deformed. The invention claimed in my patent application, however, requires a catalyst member that is bendable or conformable and that retains the catalytic coating on the carrier when the carrier is bent or curved. This is not taught or suggested by EP0831211.

19. United States Patent Number 4,798,770 (Donomoto) and Draghi (6,042,879) are cited in the Examiner's Answer at page 7, and these are relied upon for the teaching of an anchor layer comprising nickel and aluminum. Neither Donomoto nor Draghi, however, teaches providing a conformable or bendable catalyst member as claimed in my patent application.

20. I have reviewed United States Patent Numbers 5,204,302 (Gorynin) and 5,204,302 (Rondeau), which are used together with EP0831211 and Ishida to reject claims 1-3, 5-6, and 30-36 on pages 8-12 of the Examiner's Answer. It is acknowledged that Gorynin teaches at column 9, lines 64-57, rolling a corrugated catalyst strip into a cylinder. Gorynin is discussed in my specification at page 2 lines 17 to page 3 line 6. Gorynin does not teach or suggest providing a catalyst member that is bendable along its length and that can be inserted into a curved or bent exhaust pipe and retain the catalytic coating layer. Rondeau is not relied up for teaching bendable catalyst members, and as discussed above, EP0831211 and Ishida fail to teach catalyst members that are bendable along their length and retain catalytic coating.

21. In summary, none of the references cited in the Examiner's Answer either alone or together teach or suggest all of the limitations of my claimed invention, namely a bendable carrier member that can be bent along its length and retain catalytic coating on

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the carrier when the catalyst member is bent or curved to fit into a bent or curved exhaust pipe. Furthermore, conformable catalyst members as defined by my presently claimed invention performed unexpeetedly better than rigid catalyst members when inserted into exhaust pipes of a motorcycle in the removal of noxious components of the exhaust gas.

22. I hereby deelare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents that may issue thereon.

IN WITNESS WHEREOF, I have executed this instrument on the date indicated below.

10-29-07
Date

Michael P. Galligan
Michael P. Galligan

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EXHIBIT A

2001-01-1823

Flextube™ Catalyst Performance In 4-Stroke Motorcycle Exhaust Systems Is Demonstrated

M.P. Larkin, J.C. Dettling, M.P. Galligan
Engelhard Corporation
101 Wood Avenue
Iselin, New Jersey 08830-0770
USA

Abstract

An analysis of 4-stroke motorcycle emission systems indicates that a heat tube has the potential for meeting the regulatory standards if the location in the exhaust pipe matches the specific operating temperature requirements of the device. The location of a heat tube is determined by the diameter and shape of the exhaust pipe. Since the exhaust flowrate and temperature across the catalytic device determine its effectiveness, it is suggested that a flexible catalyzed tube, that could be placed anywhere in the exhaust, would have a greater potential than a rigid heat tube for solving a wide range of emission application needs. To maximize the benefit from such a simple cost effective device, the application of the "flex-tube catalyst" was studied over a wide range of conditions.

A test matrix that used high and low levels of Pt/Rh ratio and tube diameter was used to study "flex-tube catalyst" performance in 4-stroke motorcycle exhaust systems. Engine variables include inlet temperature, AFR, exhaust flow and backpressure. Catalyst variables that were probed included tube diameter, precious metal ratio, and rigid or Flextube™ design. Data will be presented to show the benefits of such a device in various configurations. Performance is assessed by comparing the conversion of pollutants at various temperatures and flowrates.

Introduction

The emission regulations for both 2-stroke and 4-stroke 2-wheelers are being tightened worldwide .[1] There are some significant differences in the emissions between the 2-stroke and 4-stroke engines. The 2-stroke have much higher HC emissions, and generally have lower exhaust-gas temperatures. Both 2-stroke and 4-stroke can have high CO emissions, especially if the engines are run rich.[2]

For a 4-stroke motorcycle, the higher exhaust-gas temperatures and the lower HC emissions present an opportunity to employ novel substrates for the catalytic oxidation of HC and CO. A current practice is to install a catalyzed rigid tube in the exhaust pipe between the engine and the muffler. This paper discusses experimental results to install a catalyzed flexible tube into the exhaust pipe. Figure 1 shows typical Flextube™ and rigid tube samples. Flexible tubes have the advantage of conforming to the bends in the exhaust pipe close to the engine. This allows for more rapid lightoff of the catalyst since temperatures are hotter closer to the engine. It also positions the catalyst directly along the wall of the bend, which is where the gases will sweep as they turn through the bend. This positioning, along with the corrugations of the Flextube™, enhance mass transfer in a region of the exhaust where the gases have sufficient thermal energy to take advantage of the improved mass transfer.

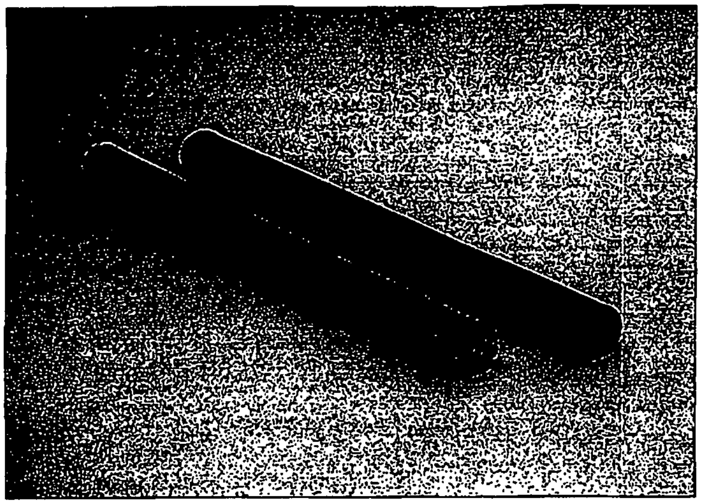

Figure 1
Typical Flextube™ and Rigid Heat Tubes

Experiments

Bench Engine Evaluation

Steady-state evaluations were performed using a 125-cc, 4-stroke motorcycle engine. The engine was coupled to a dynamometer for power absorption and load control. The engine was operated with a computer-based control and data acquisition system. The engine was instrumented to measure inlet and exit temperatures for the Flextube™, static pressure at the engine exhaust, throttle position, engine speed and load. In addition, an exhaust gas sample was taken downstream of the tubes. The sample was analyzed for CO, CO2, HC, O2, NOx, and SO2.

The engine's exhaust system was modified to facilitate installation of samples using a Flextube™ holder that was specifically fabricated and installed to study the devices. The Flextube™ samples were held in place by three machine screws evenly spaced around the perimeter of the sample at the inlet and exit ends. Each sample was installed with its inlet face at the same position in the exhaust system. The inlet face of each sample was 20 cm downstream from the engine exhaust port. The gas-stream temperature was measured 0.6 cm upstream of the tube inlet and 2.5 cm downstream of its exit.

For each steady-state condition, the engine was controlled to a constant speed and throttle setting for a period of five minutes. Temperatures, pressures and gas emissions are recorded once per second. Values for the final 30 seconds of the period are averaged and reported. Tube inlet temperatures ranged from about 350C at idle to about 725C at a throttle setting of 65%. The exhaust AFR was controlled by the engine, and ranged from a high of about 17.5 at idle to a low of 13 at 65% throttle setting.

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Vehicle Evaluation

A 4-stroke, 80-cc motorbike was used to evaluate samples over the ECE R40 drive cycle. The bike's exhaust system was modified to allow easy installation of Flextubes™. A 30-cm length of stainless steel tubing with flanges on each end was added to the exhaust system between the engine exhaust and the muffler inlet. The tube inlet was positioned 30 cm downstream from the engine exhaust port. Thermocouple housings were located 1.2 cm from the engine exhaust port, and 5 cm from the inlet and exit faces of the tube.
The 19-mm OD Flextube™ and the 21-mm OD rigid tubes were tested in a 22-mm ID tube. The 24-mm OD Flextube™ and the 27-mm OD rigid tube were tested in a 34-mm ID tube.

All samples were tested twice, and the results were averaged. If the HC and CO2 mass emissions did not agree within ten percent, the test was repeated. A blank 19-mm OD x 260-mm L Flextube™ was tested in each tube holder to provide a baseline for the calculation of HC and CO conversions.

Design of Experiments

The catalyst technology used is Engelhard's MC208 technology. It is based upon patented segregated washcoat technology which permits optimum dispersion and distribution of the precious metals to maximize their performance.[3]
In order to measure the effectiveness of Flextubes™ and rigid tubes, the tube diameter and the Pt/Rh ratio were each varied at two levels. The length of all samples was held at 260 mm.

Table 1
Values of Flextube™ Design Parameters

	High	Low
Pt/Rh ratio	20/1	5/1
Tube inner diameter (mm)	14	15.5
Tube outer diameter (mm)	19	24

Table 2
Values of Rigid Tube Design Parameters

	High	Low
Pt/Rh ratio	20/1	5/1
Tube inner diameter (mm) .	19	24
Tube outer diameter (mm)	21	27

Discussion and Results

Bench Engine Testing

Flextubes™ vs Rigid Tubes

All samples were evaluated for HC and CO conversion under steady-state conditions on an engine dynamometer. The results show that the Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions.

The following four figures highlight the performance differences between the Flextubes™ and rigid tubes. The performance data of the smaller diameter Flextube™ and rigid tubes are charted together, as are the data for the larger diameter Flextube™ and rigid tube. The HC and CO conversions for all of the samples were measured at inlet temperatures ranging from 350C to 750C. Figures 2a and 3a show the HC and CO

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conversion, respectively, for the 19-mm OD Flextube™ and the 21-mm OD rigid tube. Figures 2b and 3b show the HC and CO conversion, respectively, 24-mm OD Flextube™ and the 27-mm OD rigid tube.

Steady-state bench engine testing showed that the Flextubes™ achieved higher HC and CO conversion than did rigid tubes of similar dimensions. The 19-mm Flextube™ had HC conversions from 5% to 15% greater, and CO conversions between 0% and 15% greater, than those of the 21-mm rigid tube. The 24-mm Flextube™ had HC conversions from 5% to 20% greater, and CO conversions between 10% and 20% greater, than those of the the 27-mm rigid tube.

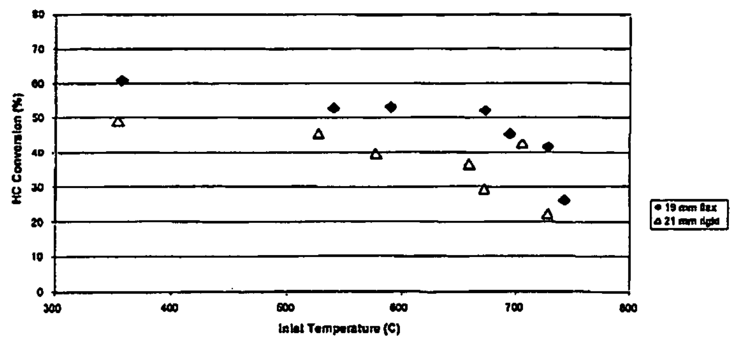

Figure 2a: Flextubes Achieve Higher HC Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 280-mm L Tubes

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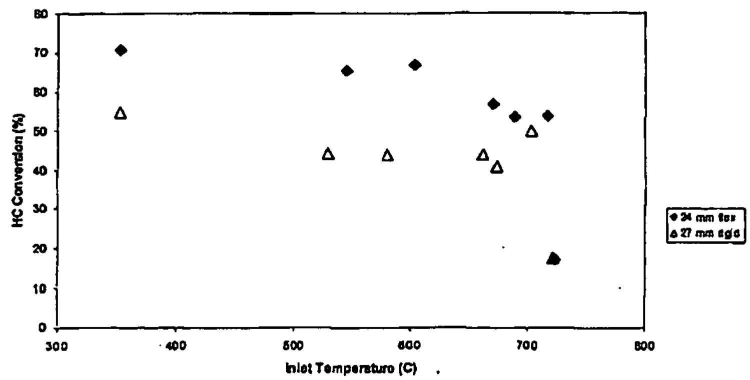

Figure 2b: Flextubes Achieve Higher HC Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 250-mm L Tubes

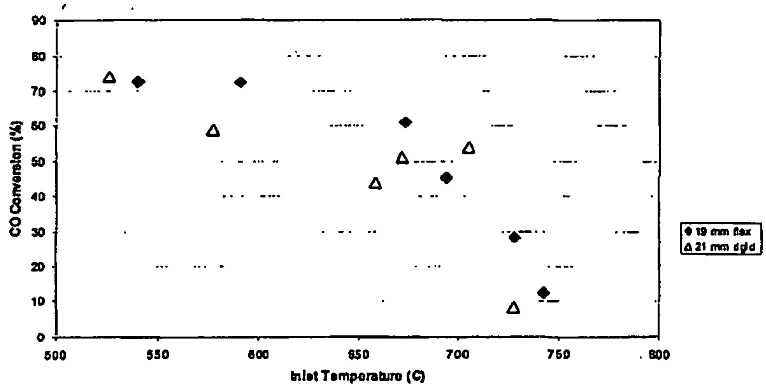

Figure 3a: Flextubes Achieve Higher CO Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 250-mm L Tubes

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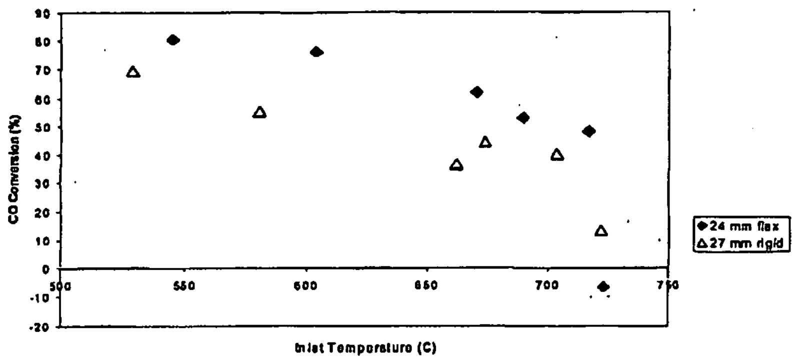

Figure 3b: Flextubes Achieve Higher CO Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

Effect of Flextube™ Diameter

Bench engine testing showed that both HC and CO conversion were improved by using a larger-diameter Flextube™. As diameter increases, total catalyst surface area increases. The 24-mm OD Flextube™ generally achieved about 10% more HC and CO conversion than the 19-mm OD Flextube™. Figure 4a shows the improvement in HC conversion for the 24-mm OD Flextube™. Generally, the 24-mm OD Flextube™ achieved HC conversions that were between 5% and 13% higher than those of the 19-mm OD Flextube™. Figure 4b shows the improvement in CO conversion for the 24-mm OD Flextube™. Generally, the 24-mm OD Flextube™ achieved CO conversions that ranged between 0% and 20% greater than those of the 19-mm OD Flextube™. In Figure 4b, the highest-temperature set of datapoints show the 19-mm OD Flextube™ with 12% CO conversion, and the 24-mm OD Flextube™ with -6% CO conversion. This is because the engine exhaust was rich at this point, and the higher HC conversion of the 24-mm OD Flextube™ resulted in higher CO make under the rich conditions.

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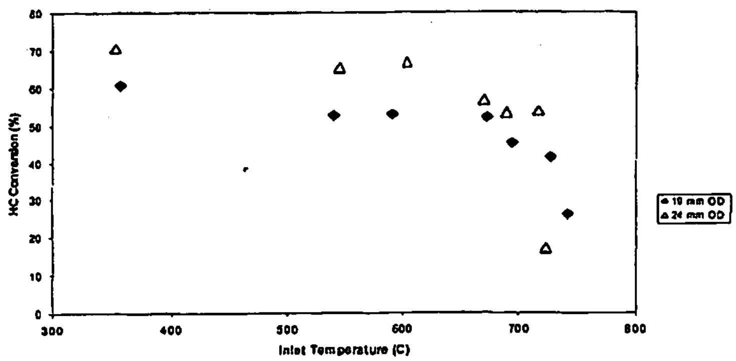

Figure 4a: Larger Diameter Flextubes Achieve Higher HC Conversion
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

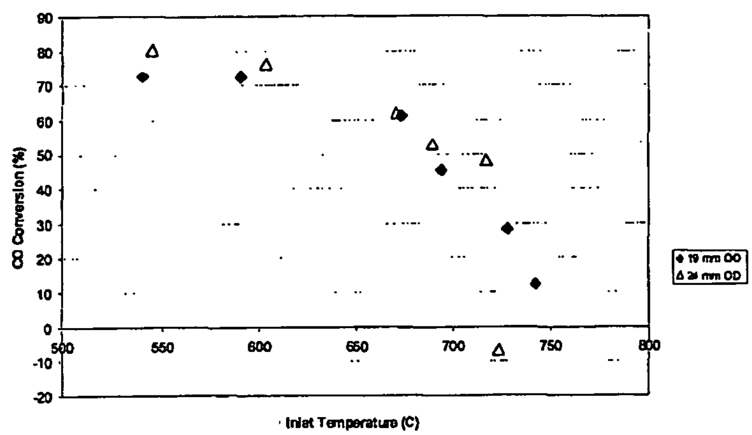

Figure 4b: Larger Diameter Flextubes Achieve Higher CO Conversion
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

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Effect of Pt/Rh Ratio

The effect of Pt/Rh ratio was measured on the bench engine. Flextubes™ were catalyzed with MC20B catalyst technology, using either a Pt/Rh ratio of either 5/1 or 20/1. Steady-state tests showed that the 20/1 ratio performed as well as the 5/1 ratio for HC conversion. Figures 5a and 5b show the HC conversion of the 19-mm OD Flextube™, and the 24-mm OD Flextube™, respectively, with Pt/Rh ratios of 5/1 and 20/1.

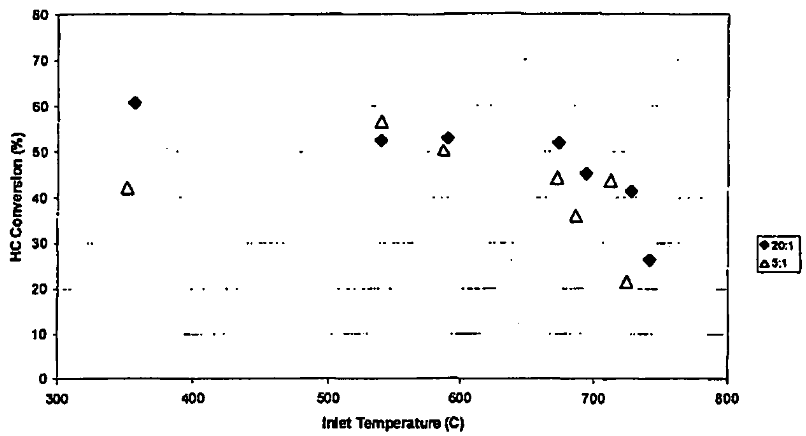

Figure 5a: 20/1 Pt/Rh Flextube Achieves HC Conversion Equal to 5/1 Pt/Rh Flextube
MC20B on 19-mm OD x 260-mm L Flextubes

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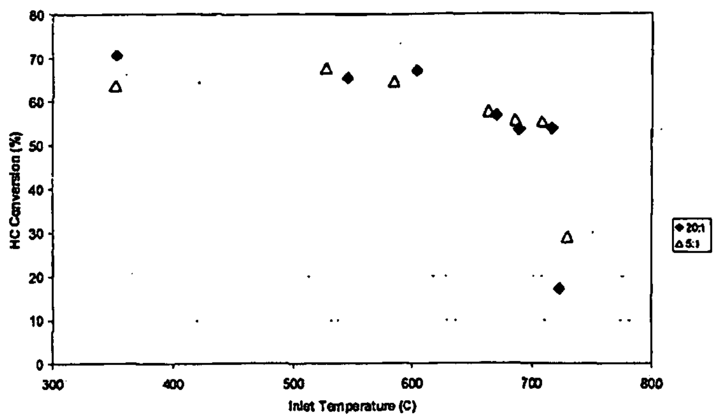

Figure 5b: 20/1 Pt/Rh Flextube Achieves HC Conversion Equal to 5/1 Pt/Rh Flextube MC20B on 24-mm OD x 260-mm L Flextubes

The final set of steady-state engine bench tests was a comparison between a 20/1 Pt/Rh 24-mm OD Flextube™ and a 5/1 Pt/Rh 27-mm OD rigid tube. Figures 6a and 6b show the HC and CO conversions, respectively, of the 24-mm OD Flextube™ coated with 20/1 Pt/Rh and the 27-mm OD rigid tube coated with 5/1 Pt/Rh. The 24-mm OD Flextube™ achieved significantly higher HC conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340C, the Flextube™ achieved 70% HC conversion and the rigid tube achieved about 20% HC conversion. The Flextube™ achieved about 20% higher HC conversion than the rigid tube until the last two steady-state conditions. These final steady-state conditions, obtained at 35% and 45% of full throttle, may represent a space velocity limitation of tubes of these dimensions.

The 24-mm OD Flextube™ achieved higher CO conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340C, the Flextube™ achieved 83% CO conversion and the rigid tube achieved about 70% CO conversion. The Flextube™ achieved higher CO conversions than the rigid tube under all steady-state conditions except the last condition. At this condition, the exhaust became rich, and the higher HC conversion of the Flextube™ resulted in higher CO make in the rich exhaust.

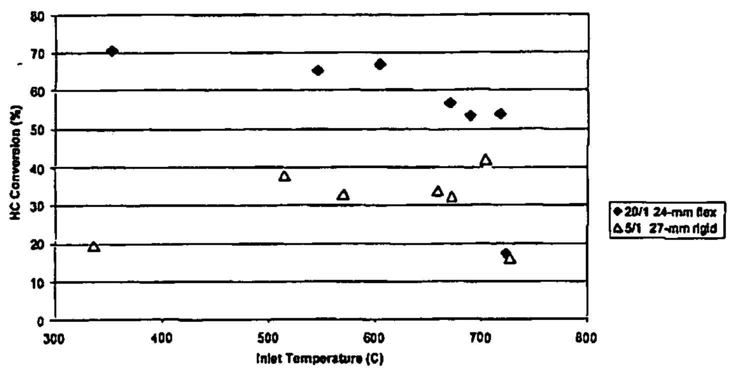

Figure 6a: 20/1 Pt/Rh Flextube Outperforms 5/1 Pt/Rh Rigid Tube
Steady-State HC Conversion on 125-cc 4-S Engine
MC20B Catalyst on 260-mm L Tubes

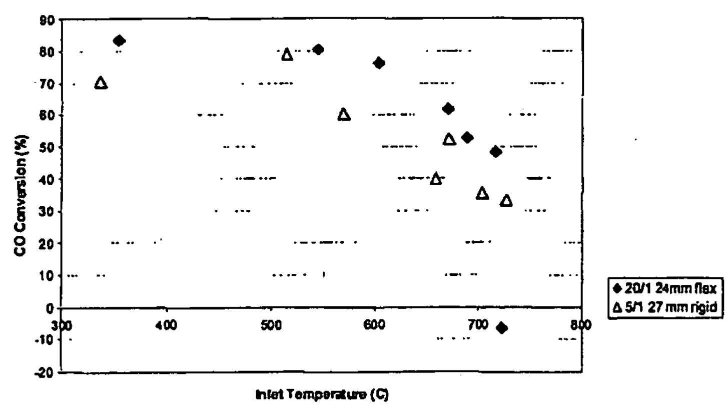

Figure 6b: 20/1 Pt/Rh Flextube Outperforms 5/1 Pt/Rh Rigid Tube
Steady-State CO Conversion on 125-cc 4-S Engine
MC20B Catalyst on 260-mm L Tubes

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ECE R40 Results

All samples were tested twice using the ECE R40 drive cycle. The 19-mm OD Flextubes™ and the 21-mm OD rigid tubes were tested in a 22-mm ID tube. The 24-mm OD Flextube™ and the 27-mm OD rigid tube were tested in a 34-mm ID tube. ECE R40 testing shows that the Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions.

Effect of Pt/Rh Ratio

The effect of Pt/Rh ratio was measured on the 4-s vehicle. Flextubes™ were catalyzed with MC20B catalyst technology, using either a Pt/Rh ratio of either 5/1 or 20/1. In the R40 vehicle tests, the 20/1-ratio Flextubes™ achieved HC and CO conversions that were about 5% less than those of the 5/1-ratio Flextube™. Figure 7 shows the HC and CO conversions of the 19-mm OD Flextubes™ catalyzed with Pt/Rh ratios of 5/1 and 20/1.

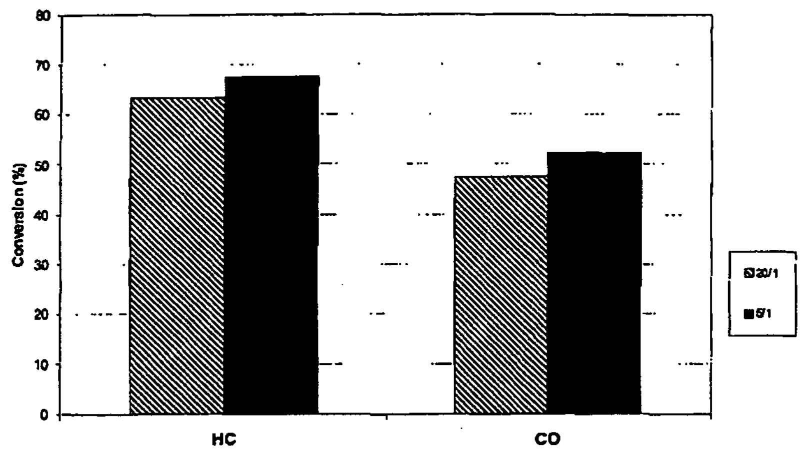

Figure 7: 20/1 & 5/1 Pt/Rh Flextubes Achieve Similar HC & CO Conversions In ECE R40 Test
19-mm OD x 260-mm L Flextubes with MC20B Catalyst

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Effect of Gap Distance

The effect of the gap distance between the OD of the Flextube™ and the ID of the exhaust pipe was noted. The vehicle was run over the R40 cycle using the 20/1 Pt/Rh 19-mm OD Flextube™. One set of tests had the Flextube™ in the 22-mm ID exhaust pipe holder, and one set of tests had the Flextube™ in the 34-mm ID exhaust pipe holder. The emissions data showed that the higher conversions were achieved when the gap distance was about 1.5 mm.

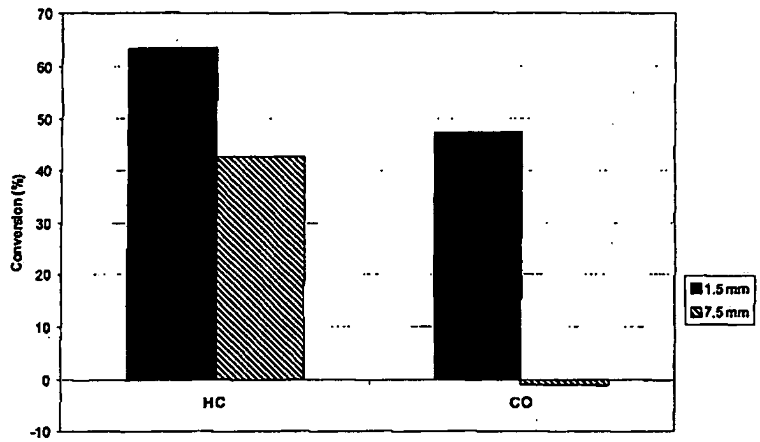

Figure 8: The 1.5-mm Gap Between Flextube and Exhaust Pipe Yields Higher HC & CO Conversion than the 7.5-mm Gap 20/1 Pt/Rh MC20B Catalyst on 19-mm OD x 260-m L Flextube

Flextube™ vs Rigid R40 Tests

The vehicle R40 testing showed that a Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions. Figures 9a and 9b compare the HC and CO conversions between a Flextube™ and a rigid tube of similar diameters. Figure 9a shows the small-OD tube data, and Figure 9b shows the large-OD tube data.

In the R40 testing, the 19-mm OD Flextube™ achieved HC and CO reductions of 63% and 47%, respectively. The 21-mm OD rigid heat tube achieved 38% HC reduction and 40% CO reduction. The 24-mm OD Flextube™ achieved 59% HC reduction and 32% CO reduction, and the 27-mm OD rigid heat tube achieved 44% HC reduction and 29% CO reduction.

The differences between the Flextube™ and rigid tube HC conversions were larger than the differences in CO conversions. This is probably due to limitations of O2 availability.

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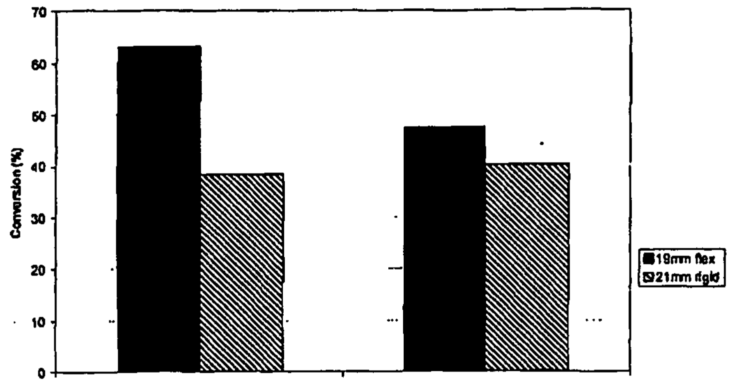

Figure 9a: Small-Diameter Flextube Achieves Higher HC & CO Conversion than Rigid Tube in ECE R40 Testing 20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

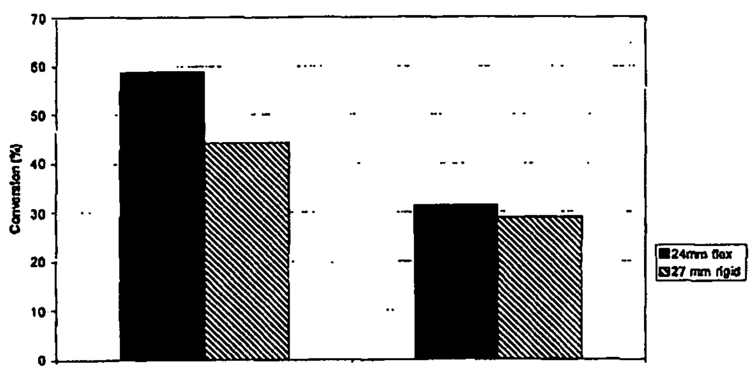

Figure 9b: Large Diameter Flextube Achieves Higher HC & CO Conversion than Rigid Tube in ECE R40 Testing 20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

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Effect of a Close-Coupled Flextube™

A 19-mm OD x 260-mm L Flextube™ and a 21-mm OD x 260-mm L rigid tube were both catalyzed with 20/1 Pt/Rh MC20B catalyst technology. The Flextube™ was tested in a close-coupled position, with the inlet located 50 mm downstream of the engine exhaust port. Both the Flextube™ and the rigid tube were tested at a location where the inlet was 300 mm downstream of the engine exhaust port. Figure 10 is a schematic drawing of where the Flextube™ was positioned. Figures 11a & b show the results of these tests. The close-coupled Flextube™ achieved twice the HC conversion as the rigid tube located 300 mm downstream. The close-coupled Flextube™ achieved 50% more CO conversion than the rigid tube located 300 mm downstream. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, the HC conversion increased from 63% to 81%, and the CO conversion increased from 47% to 62%. These tests demonstrate that the Flextube™ is able to deliver more emission reduction if it is located closer to the engine exhaust. In a close-coupled position the Flextube™ can take full advantage of the turbulent flow and higher temperature.

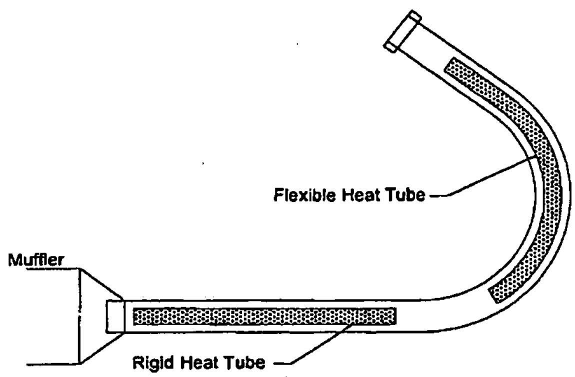

Figure 10
Schematic of Close-coupled Flextube™

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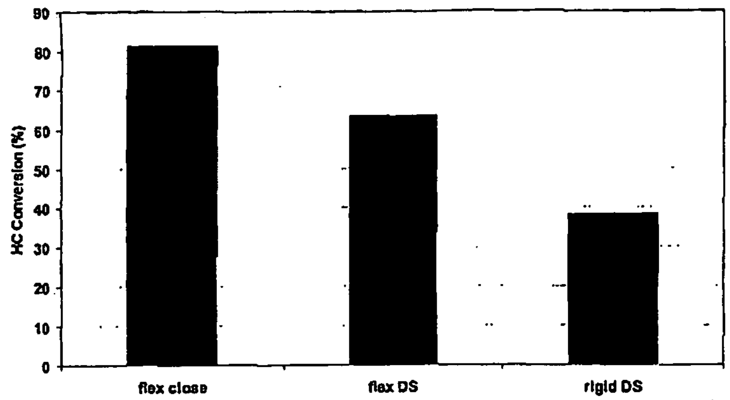

Fig 11a: Close-Coupled Flextube Achieves 100% more HC Conversion than a Rigid Tube Located 300 mm Downstream
20/1 Pt/Rh MC20B Catalyst Technology on 260-mm L Tubes

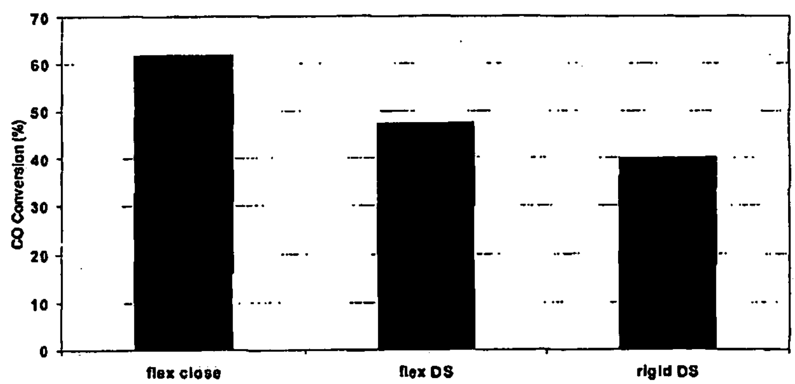

Fig 11b: Close-Coupled Flextube Achieves 50% more CO Conversion than a Rigid Tube Located 300 mm Downstream
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

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Conclusions

The ECE R40 bike results show the benefits of utilizing a Flextube™ in a close-coupled position. In comparison with a rigid tube located 300 mm downstream, the close-coupled Flextube™ achieved 50% more CO conversion and 100% more HC conversion. Tests were also run to measure the effect of close-coupling on the Flextube™ itself. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, it achieved 33% more CO conversion and 25% more HC conversion.
The ECE R40 bike results and the steady-state engine testing both demonstrate that Flextubes™ achieve higher HC and CO conversions than rigid tubes of similar dimensions. In the R40 tests, Flextubes™ achieved between 15% and 25% higher HC conversion than the rigid tubes and between 3 and 7% more CO conversion than the rigid tubes.

Flextubes™ achieve higher HC and CO conversion by providing improved mass transfer. In the close-coupled position, they also take advantage of better chemical kinetics by being located in a position where the exhaust gases are hotter. This is especially important for drive cycles that do not allow for adequate warm-up of the exhaust system.

References

[1] AECC (Association for Emission Control by Catalyst), "Overview of Global Emission Standards for Two- and Three-Wheeled Vehicles", Brussels, Belgium, 9 November 2000

[2] J.C Dettling, M. Galligan, M. Larkin, J. Adomaitis, "Emission Control Strategies for 2- and 4-Stroke Motorcycles in India", SAE 2000-01-0002

[3] H.S. Hwang, J.C. Dettling, J.J. Mooney, "Catalytic Converter Development for Motorcycle Emission Control", SETC '97 SAE 972143

RELATED PROCEEDINGS APPENDIX

None.